THE FORESTS OF THE FLATHEAD VALLEY, MONTANA.[1]

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY LXVII.

HARRY N. WHITFORD.

(WITH MAP AND TWENTY-THREE FIGURES)

INTRODUCTION.

THE factors concerned in the grouping of plants are classified by SCHIMPER[2] as climatic and edaphic. When the climate of any region is such that a particular form of plant is favored, in most instances it gives character to the vegetation. For example, in the eastern United States the climate favors the tree form and gives rise to a "forest formation." If the grass form predominates, however, a "prairie formation" is the result. Again, if the climate be such that the cactus form gives the tone to the landscape, the "desert formation" is developed. Two such formations are shown in *fig. 1*, which is a view of a portion of the Flathead valley looking west from a high mountain. In the distance on the west side of the valley is a prairie formation; on the east side is a forest formation.

However, if one stands on a mountain top and looks down into these formations, he will observe that isolated areas in the forest do not contain trees, but may have a prairie, a swamp, a clearing, or a heath. The prairie formation may contain forests along streams or on protected hillsides. Also, in the forest formation there may be areas occupied almost exclusively by one, two, or more species of trees; while at a little distance there may be another area with entirely different trees. In other words, the composition of the forest changes from place to place. To distinguish these local groups from the general climatic grouping, SCHIMPER has called them "edaphic formations." By other authors they have been called "plant societies," "plant associations," or merely "plant forma-

[1] This paper is based on work as a collaborator in the U. S. Bureau of Forestry, to which acknowledgment is here made for permission to publish.

[2] SCHIMPER, A. F. W., Plant geography upon a physiological basis (translated by FISHER) 159–161. 1903.

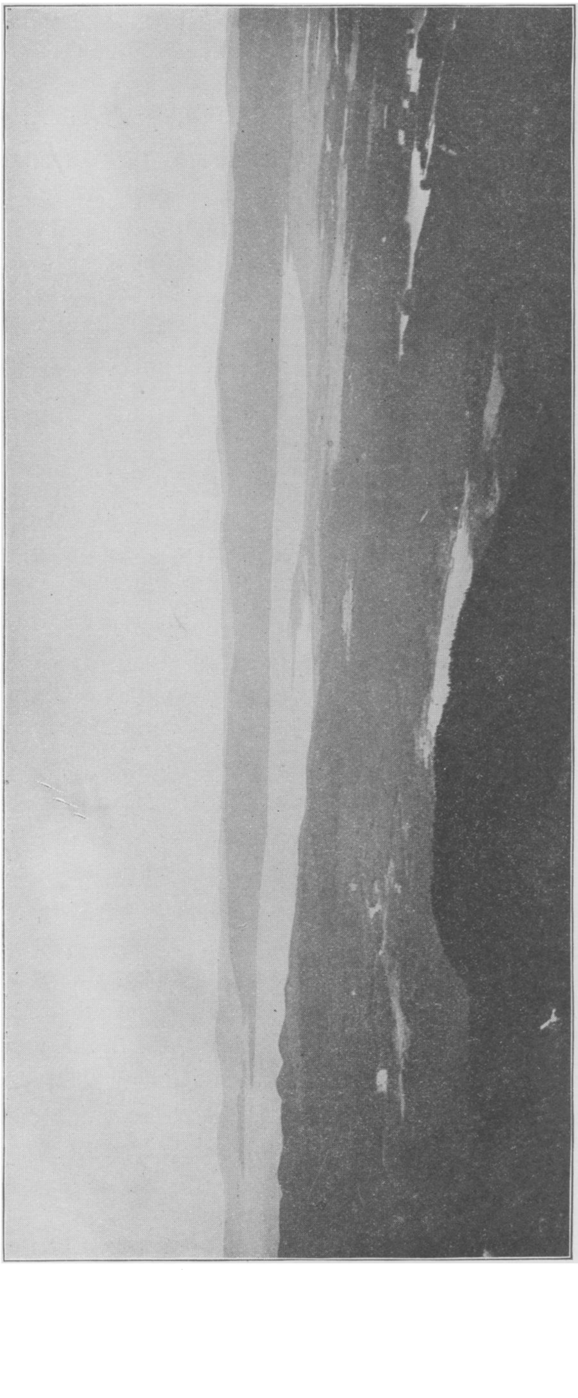


FIG. 1.—View looking southwest from a high point in the Swan Mountains from just beyond the northeast limits of the map; Flathead Lake in the distance; the point of land extending into the lake is the delta of Flathead River; on the west side of the valley at the head of Flathead Lake a prairie formation; on the east in the foreground a forest formation. The edaphic areas shown in the forest formation are Ross Lake in the immediate foreground; north and south of this meadows; to the right Echo Lake; midway between Ross Lake and the delta is "nigger" prairie. In the prairie formation the course of Flathead River may be seen by the line of forests along its banks.—From photograph by ELROD.

tions."[3] *Fig. 1* will also illustrate these smaller groups. In the foreground may be seen a pond which contains its characteristic plants; to the right of this a meadow; and between the pond and Flathead Lake a local prairie. These are in the forest formation. While the soil factors determine primarily the variety of the plant landscape, other factors must be taken into consideration. In this paper, however, the convenient term "edaphic formation" will be used.

COWLES[4] was the first to show clearly that plant societies are not static, but dynamic. In brief, his contention is that the plant society changes with the physiographic changes that are constantly going on. In a former paper[5] I have attempted to correlate the various plant societies found in northern Michigan. In that study it is shown that the region lies in a deciduous forest formation, and that while the coniferous forest societies are present in the more xerophytic conditions, there is a tendency for them to be replaced by the climax society, the beech-maple combination. The present study, made in a region with a somewhat different climate, was undertaken to determine whether the various plant societies could be correlated in the same way. For this purpose a general survey was made of the Flathead valley, and a portion of it was selected to study in closer detail. No attempt was made to study the conditions in the higher altitudes where a different climate prevails.

PHYSIOGRAPHY.[6]

There exists a close relation between the development of the physiography of a region and the life history of its forest formation; hence the necessity of describing the topographic features of the Flathead valley. It is a well-defined physiographic unit, situated in the northwestern part of Montana, about long. 114° 30′ W. and lat. 47° 30′–49° N. (*fig. 2*). The altitude of the valley is approxi-

[3] For a discussion of the subject, see COWLES, H. C., The physiographic ecology of Chicago and vicinity. BOT. GAZETTE 31:74–76. 1901.

[4] *Loc. cit.* pp. 75–108, 145–182.

[5] WHITFORD, H. N., The genetic development of the forests of northern Michigan. BOT. GAZETTE 31:289–325. 1901.

[6] See ELROD, M. J., The physiography of the Flathead Lake region. University of Montana Bull. 17: 197–203.

mately 900^{m}, and it extends from the Canadian boundary about 160^{km}, a little to the east of south, to the low Jocko Mountains. A number of mountain ranges form its western border, and the front range of the Rocky Mountains with sub-ranges lie directly east, the

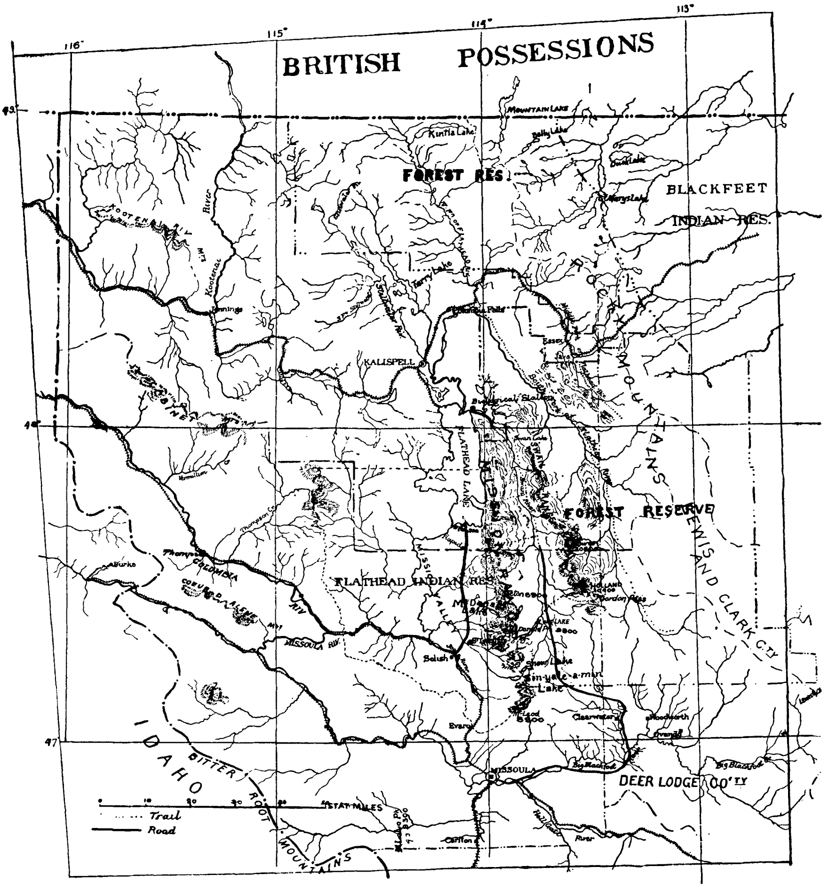
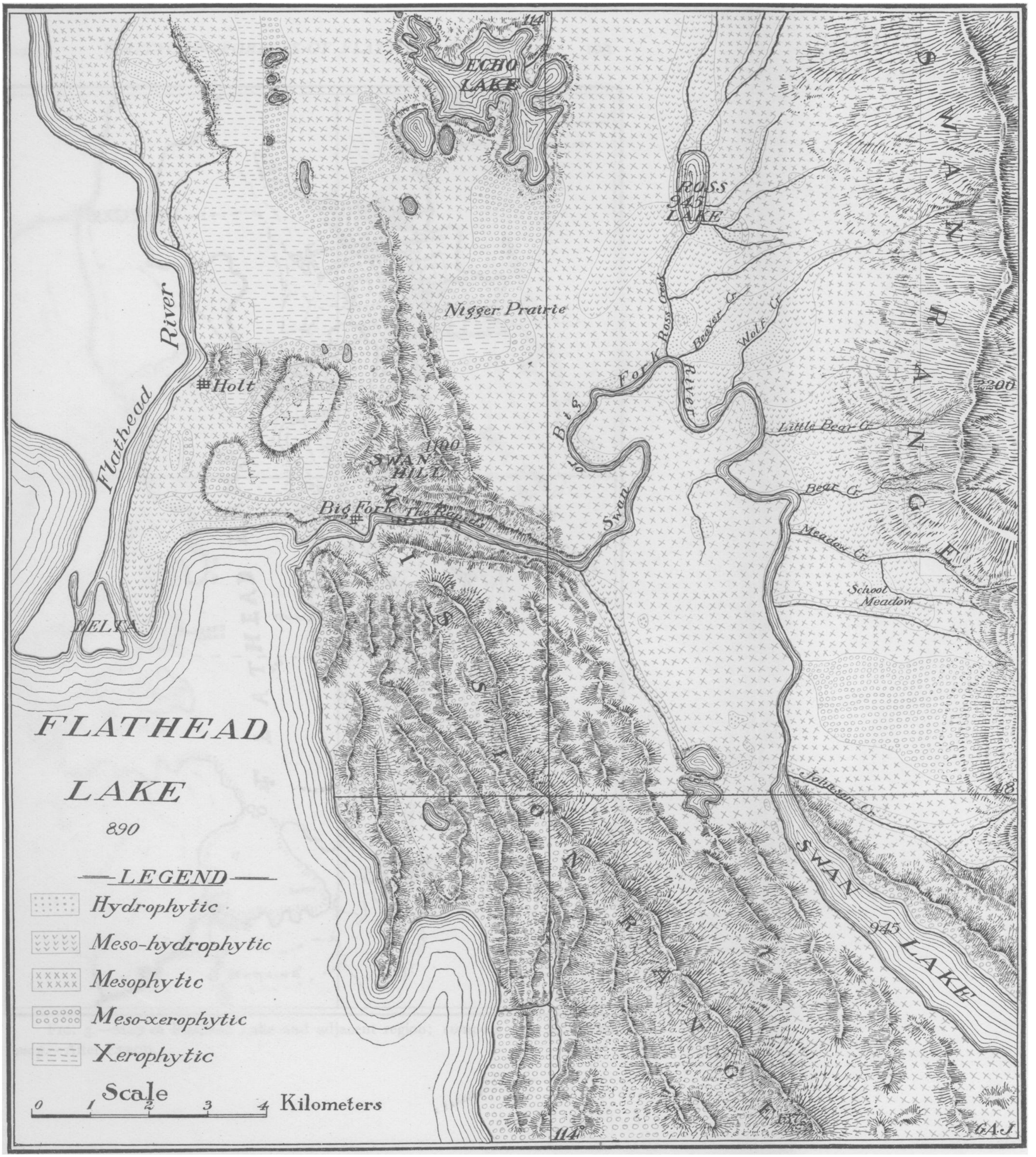


FIG. 2.—Map of northwestern portion of Montana, showing the general location of Flathead valley.—After ELROD.

valley varying in width from 16 to 40^{km}. The portion lying south of Flathead Lake is known as the Mission valley. That part with which this paper deals more especially is found in the region bordering the northeastern shores of Flathead Lake (*fig. 3* and *map*).

The main drainage system of the valley consists of the Flathead


ECHO LAKE
114
ROSS 945 LAKE
SWAN RANGE
Nigger Prairie
Flathead River
Holt
1100
SWAN HILL
Big Fork
The Rapids
Big Fork River
Swan
Ross Creek
Beaver Cr.
Wolf Cr.
2300
Little Bear Cr.
Bear Cr.
Meadow Cr.
School Meadow
Johnson Cr.
48
DELTA
MISSION RANGE
FLATHEAD LAKE
890
SWAN LAKE
945
LEGEND
Hydrophytic
Meso-hydrophytic
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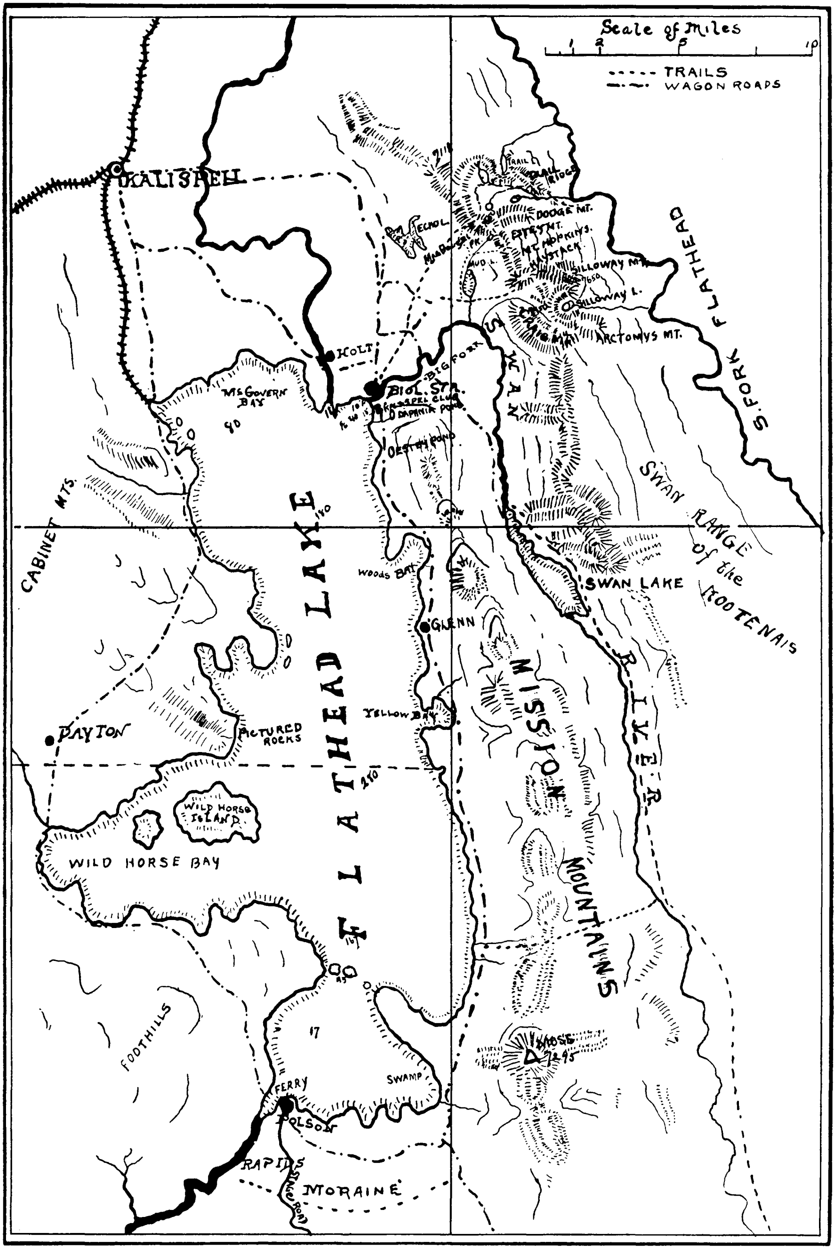

FIG. 3.—Map of Flathead Lake and adjacent region; compare with *fig. 1* and *map*.—After ELROD.

Lake; its principal inlet, Flathead River; and its outlet, the Pend d'Oreille River. Flathead River is formed by the confluence of three branches known as the North Fork, South Fork, and Middle Fork, all of which rise in the Rocky Mountains. These flow for their entire course in valleys in the mountains and unite to form the main river near Columbia Falls. The Stillwater and Whitefish Rivers are the principal branches that lie in the Flathead valley. For about the lower half of its course through the valley, the Flathead River is a broad, sluggish, navigable stream that is constantly depositing sediment. Especially is this the case at its mouth, where a delta about 3^{km} in length has been formed (*fig. 4*).

Flathead Lake (*fig. 5*) is some 40^{km} from north to south and varies in width from 10 to 20^{km}, its altitude being 890^{m}. It is a remnant of a former lake of much greater extent, which probably covered a large portion of the valley at its head. An old outlet near Dayton (*fig. 3*), some 120^{m} above the present level of the lake, and terraces at approximately the same height, indicate the former distribution of the waters of the lake. The Pend d'Oreille River (*figs. 5, 6*), the present outlet, has cut its way through a huge moraine at the foot of the lake. This moraine no doubt acted as the dam that backed up the water over the low valley lying to the north. The river rapidly cut its way through this moraine until its present condition was developed. This erosive process is going on much more slowly today because the river channel has reached bed rock.

The Mission Range lies to the east of the lake and the Mission valley. This is a distinct range separated from the other mountains on the east by the Swan River valley. It has an altitude of approximately 2750^{m} at its southern end. From this altitude the mountains become gradually lower until near the north end of the lake, where they merge imperceptibly into the valley. The Swan River valley opens into the Flathead valley where these mountains end (*map* and *fig. 1*). It is in reality only an arm of the latter, and during the time of the greatest extension of Flathead Lake the water probably backed up into this valley and formed an embayment. As the Pend d'Oreille River cut its way through the moraine at the foot of Flathead Lake, the level of the water in this embayment was lowered. But some time before the present condition was reached, a moraine

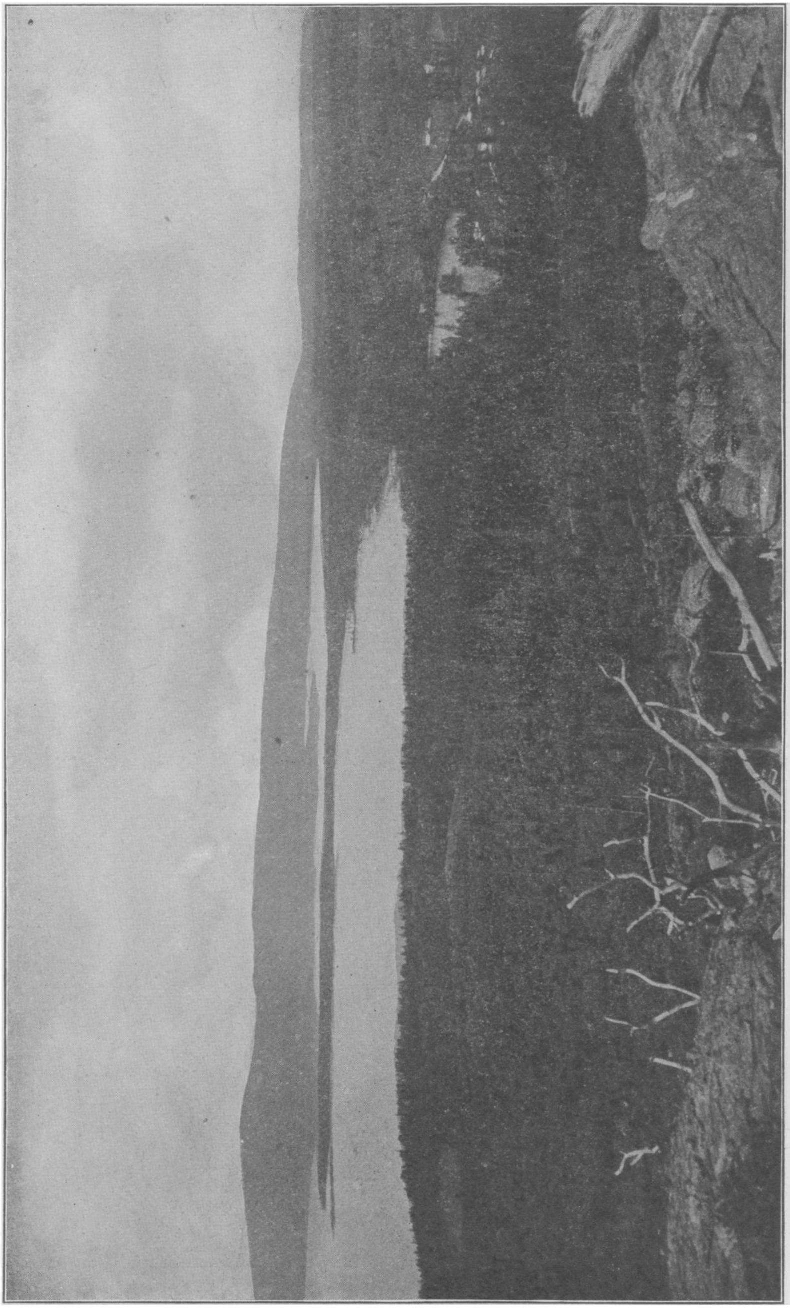

FIG. 4.—Looking west from Mission Mountains across the northern end of Flathead Lake; the delta is seen in the distance; on the right is the town of Big Fork near the mouth of Swan River; beyond Big Fork is a portion of the prairie region; in the center and on the left is the forested region on the west slopes of the Mission Mountains; the forests here have been nearly destroyed by fire.—From photograph by ELROD.

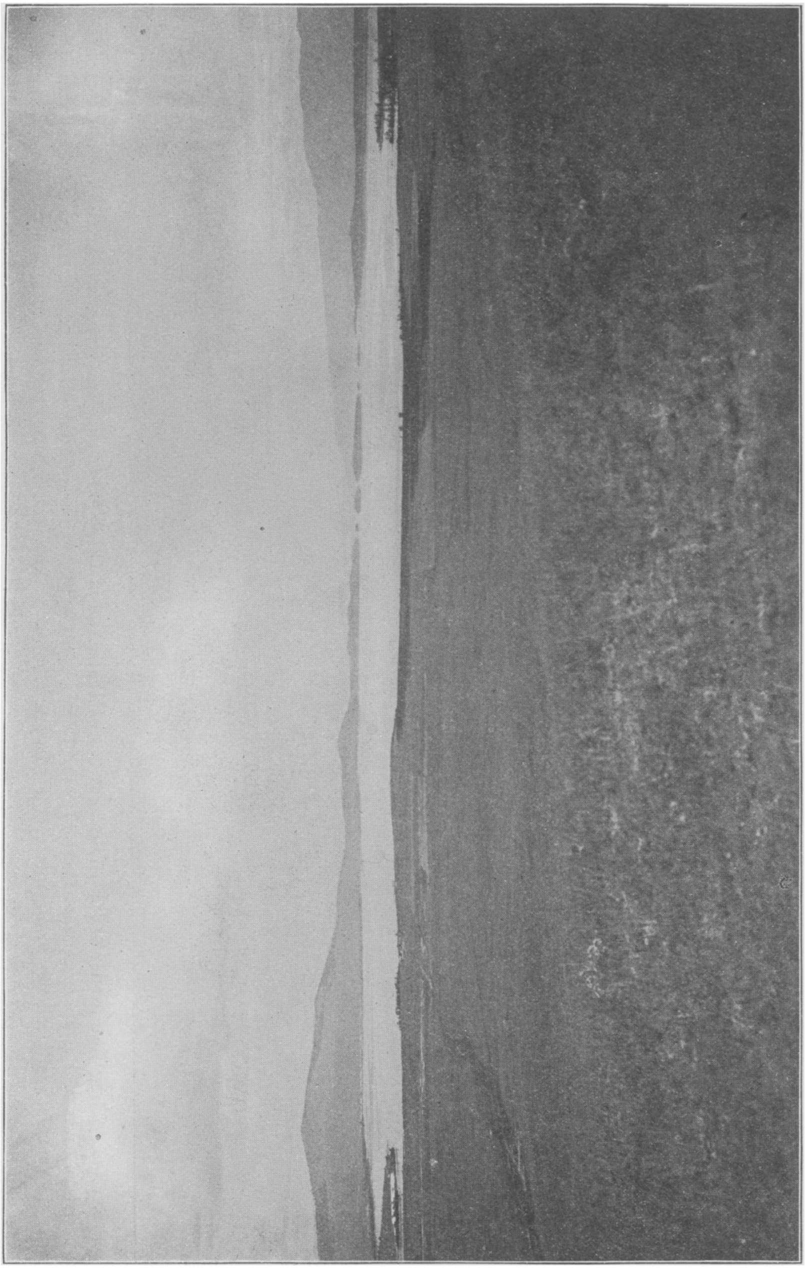

FIG. 5.—Flathead Lake looking north from moraine at south end; in the distance a chain of islands stretching nearly across and dividing the lake into two unequal parts, the greater portion being to the north; the islands mark the beginning of the forested region; to the left the outlet of Pend d'Oreille River, a part of which is seen in *fig. 6*.—From photograph by ELROD.

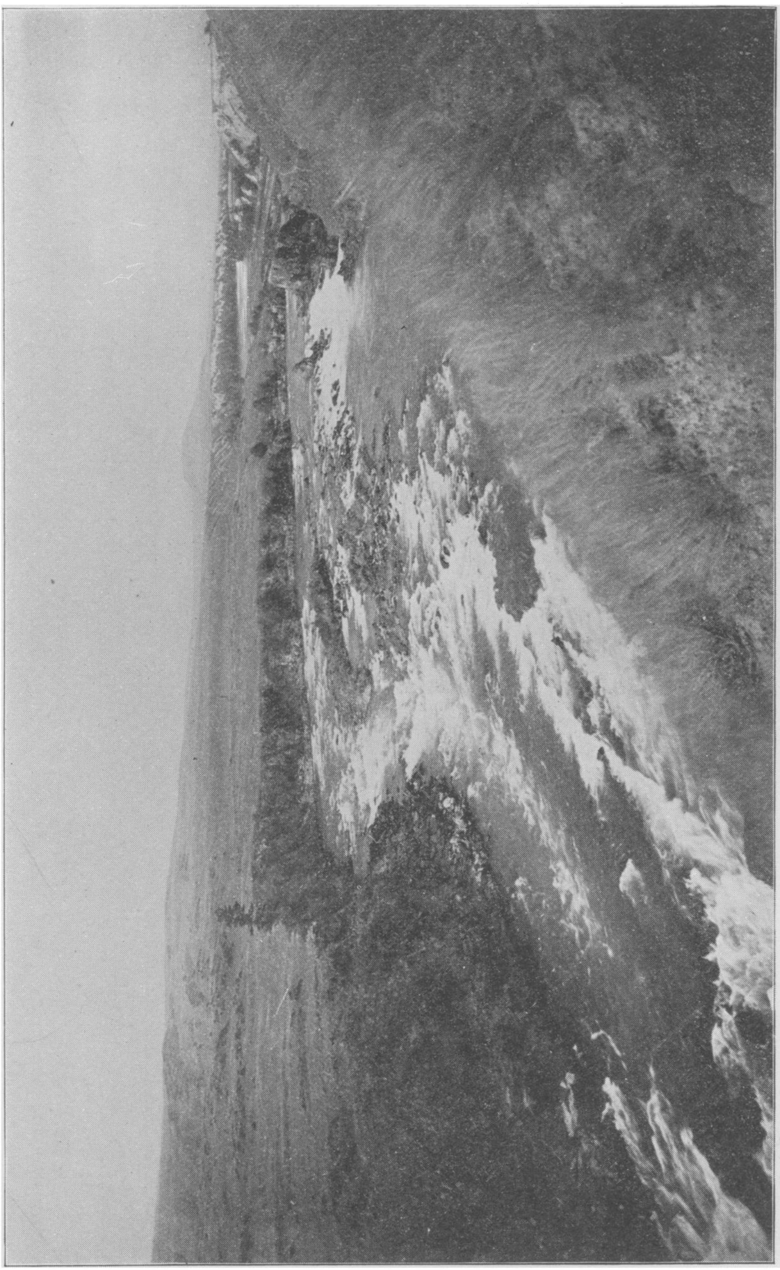

Fig. 6.—Pend d'Oreille River, the present outlet of Flathead Lake; the river has cut through moraine shown in *fig. 5;* as its channel was eroded the level of the lake was lowered, and the receding waters left broad areas of level land.—From photograph by Elrod.

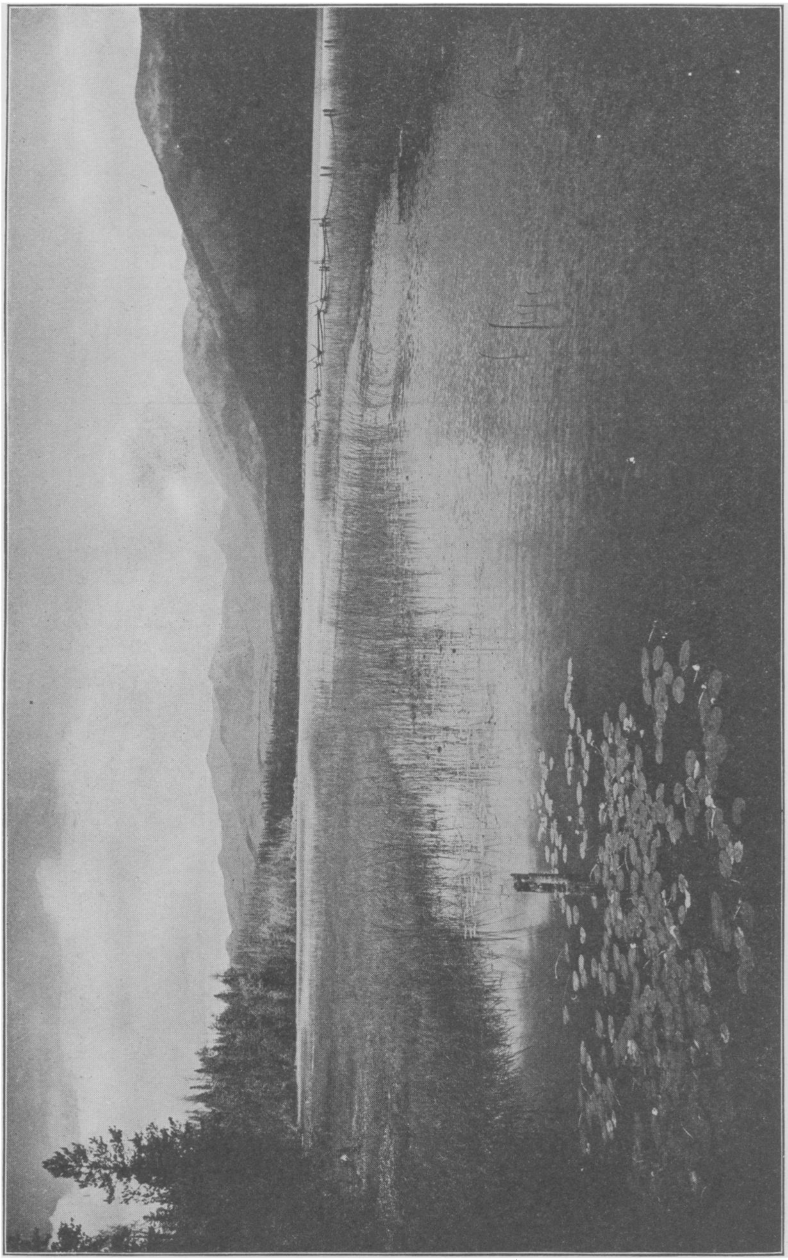

FIG. 7.—Looking north from the south end of Ross Lake; in the deeper waters are *Nuphar advena*, *Brasenia purpurea*, *Potomageton* sp., etc.; around the borders are sedges and grasses; outside these is the Engelmann spruce formation; the meadow is submerged during the spring and early summer months.

was probably thrown across the mouth of the Swan valley, and thus its connection with the main lake was cut off. A gap in the Mission Range offered a favorable place for the water thus cut off to make its escape. This outlet, of course, marked the beginning of that portion of the Big Fork River known as the "rapids" (*map*). Just as the present condition of the drainage system of Flathead valley is only a stage in the history of the destruction of the former enlarged Flathead Lake, so the existing drainage system of the Swan valley is only a stage in the history of the destruction of the former more extended Swan Lake. This system consists of Swan Lake; its inlet, Swan River; and its outlet, Big Fork River. Swan Lake is a body of water some twelve miles long and, except at its upper end, very narrow. It passes almost imperceptibly into the Big Fork River. This is a meandering stream which with its branches drains the valley and the mountains lying to the east and west of it. With the exception of small rapids here and there, and that part of it known as the "rapids," the river is a rather sluggish stream. The valley (*fig. 8*) is approximately 945^{m} above the level of the sea. The Swan Range of the Kootenai Mountains rises abruptly from the east side of the valley to an altitude of from 1800 to 2200^{m}, and the Mission Mountains border the valley on the west.

Such, in brief, are the main features of the physiography of the Flathead valley and its arm, the Swan valley. More detailed peculiarities will be noted in connection with the discussion of the edaphic formations; for, as will be shown later, there is an intimate relation existing between the destruction of the two lakes and the development of the plant formations that are found in the valleys.

GEOLOGY.

Flathead valley is not, as one would suppose, an erosion valley, but according to WILLIS[7] it is due to a fault resulting in the downthrow of the region of the valley and an uplift of the region of the present Rocky Mountains. The northern Rocky Mountains consist of limestones, quartzites, and siliceous argillites about 2750^{m} thick. During pre-Cambrian times the whole was under water. At the beginning of the Cambrian age an uplift brought it above

[7] WILLIS, BAILEY, Structure of the front range, northern Rocky Mountains, Montana. Science N. S. **15**:86–87. 1902.

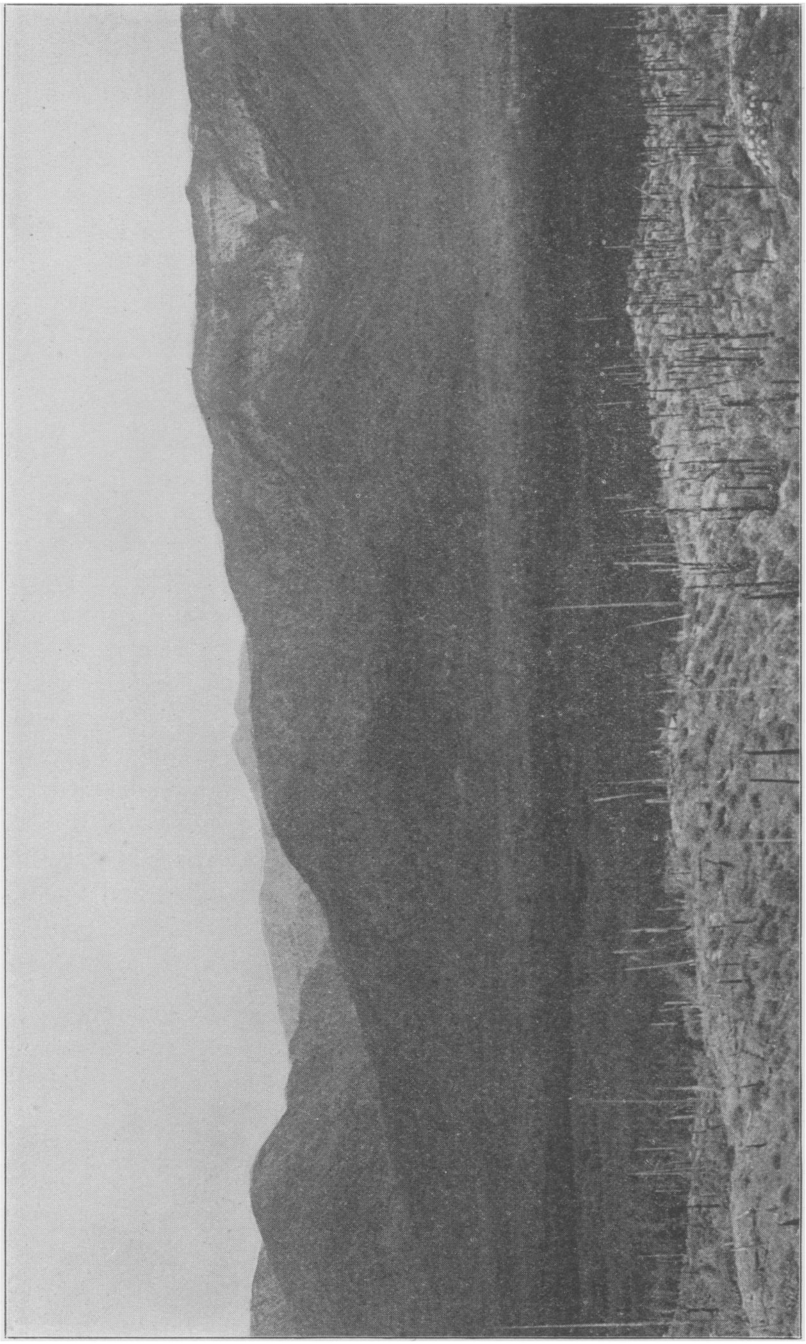

FIG. 8.—General view looking across the Swan valley from Mission Range; Swan Range in the distance; the forest in the valley is western larch-Douglas spruce type except where the lodgepole pine has come in after fires; in the foreground a portion of the Mission Range; the forests completely destroyed by fires.—From photograph by ELROD.

water, and during all the Palaeozoic and part of the Mesozoic the pre-Cambrian rocks were subjected to subaerial erosion. A movement at the close of the Jurassic again brought the sea over it. Then Cretaceous sediments of considerable thickness were deposited upon pre-Cambrian limestone and quartzite. In post-Cretaceous times a fold was overturned to the northeast. Some time in the Tertiary, probably during the Miocene, the faulting mentioned above occurred. The rocks tilt as a rule to the southeast, the northwest fault face of the rocks being very steep.

SUMMARY.

1. The Flathead valley is due to a fault, and is technically known as a rift valley.

2. The greater part of it was formerly occupied by a lake.

3. The present drainage system of the valley consists of the Flathead Lake, the Flathead River and its branches, and the Pend d'Oreille River.

4. The Swan River valley, an arm of the Flathead valley, has for its drainage lines the Swan Lake, the Swan River, and the Big Fork River with its branches.

5. These drainage systems are remnants of the former more extensive lake that occupied the valleys.

I. Climate of Flathead valley in relation to climatic formations.

It has already been shown that the climate determines the general plant formation of a region. It is important, then, that the elements of the climate be analyzed thoroughly, and it should be pointed out at the same time in just what way these elements affect the distribution of plants. In order to obtain a better understanding of the true relation of the forests of this valley, its climate will be compared with that of the northern peninsula of Michigan, where both deciduous and coniferous forests are found; and with that of the Puget Sound region, where the coniferous type of forest reaches its highest development.

There are meteorological reports from two stations in the Flathead valley. These reports, though meager in some particulars, will give a fair idea of the climatic conditions found in a prairie

formation and in a forest formation. The data collected from Kalispell, Montana, cover a period of from four to five years. This station is located in the prairie region of the valley. From a station at Columbia Falls partial meteorological data were obtained that will give an idea of the climate of the forested portion of the valley. Marquette, Michigan, was chosen as the station to represent the climatic conditions of northern Michigan; and Seattle, Washington, will stand fairly well for the kind of climate found in the Puget Sound region.[8]

TEMPERATURE.

The following table contains the latitude, longitude, altitude of the stations, the number of years data have been collected, and the mean annual and monthly temperatures (degrees Centigrade) for the four stations.

TABLE I.

Stations	Lat. Long.	Alt.	Years	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
Kalispell........	48° 10′ N. 114° 25′ W.	904m	5	−4.0	−4.5	1.5	6.0	10.5	14.0	16.5	16.0	11.0	7.0	0.5	−2.0	6.0
Columbia Falls...	About same	946	5	−5.0	−4.5	0.0	6.0	11.5	14.0	18.0	14.0	10.0	6.0	0.0	−4.5	5.5
Marquette.......	46° 34′ N. 87° 24′ W.	224	29	−9.0	−8.5	−5.0	3.0	9.0	15.0	18.0	17.5	13.5	7.0	−0.5	−5.0	5.0
Seattle..........	47° 38′ N. 122° 20′ W.	1.5	12	5.5	5.5	7.0	10.0	12.5	15.5	17.5	17.5	15.0	10.5	7.0	6.0	11.0

The significance of these figures will be clearer when it is known just how the temperature influences the various physiological processes. An examination of Table I and *fig. 9* will show that the mean monthly temperatures during the growing season is rather low as compared with regions farther south; also, during the months of May, June, July, August, September, the means for the four stations are not far apart; so that any difference in the type of vegetation in the four stations cannot be accounted for by differences in temperature during the so-called growing season. If the temper-

[8] The data given in the tables below were obtained from the following gentlemen in charge of the stations at their respective cities: Kalispell, Mont., H. B. DICK; Marquette, Mich., H. R. PATRICK; Seattle, Wash., G. N. SALISBURY. The figures for Columbia Falls, Mont., were obtained from the Climate and Crop Service Bulletin of Montana for 1900 and 1901. No sunshine records are kept at Marquette, so those from Escanaba, Mich., are taken to represent northern Michigan in that particular.

ature has anything to do with the difference in the character of the vegetation, it must be the temperature of the non-growing rather than of the growing season.

It is too often assumed that during the non-growing season physiological processes of plants are inactive.[9] Of course, this is true of growth; indeed, growth is checked and ceases rather early in the season; but photosynthesis is known to occur during the winter months. Experiments by MIYAKE[10] show that this process is active at temperatures in the neighborhood of 0° C. Among the evergreen leaves experimented upon were species of pine and spruce. One of MIYAKE'S conclusions is that starch is formed in winter, though

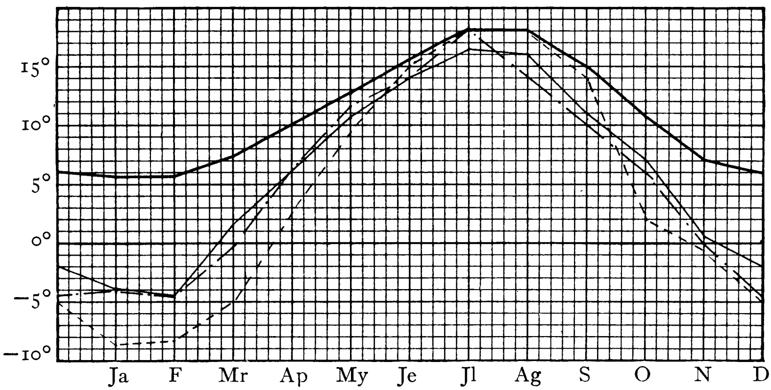

FIG. 9.—Comparative temperature for Seattle (———), Kalispell (———), Columbia Falls (——·——·), and Marquette (------); the figures are temperature Centigrade; winter temperature for Seattle comparatively high, for Marquette low, for Kalispell and Columbia Falls intermediate; summer temperature for all stations nearly the same.

in small amounts, and its translocation occurs in the same season. His work was conducted at Tokyo, Japan, where the mean temperature of the three winter months is as follows: December, 5.1° C.; January, 2.7° C.; and February, 3.5° C. If trees can do photosyn-

[9] MERRIAM says that "in computing the sum of the positive or effective temperatures a minimum of 6° C. has been assumed as marking the inception of the period of physiological activity in plants and of reproductive activity in animals." MERRIAM, C. H., Life zones and crop zones of the United States. U. S. Dept. Agric., Div. Biol. Survey, Bull. 10: 4, note 2. 1898.

[10] MIYAKE, K., On the starch of evergreen leaves and its relation to photosynthesis during the winter. BOT. GAZETTE **33**:321–340. 1902.

thetic work in the climate of Tokyo during the winter months, it is possible that more food is manufactured by the trees in the Puget Sound region, where the temperature is even higher than at Tokyo. If this be the case for the winter months, it will be even more so for the early spring and late fall months, when the mean temperatures at Seattle are as follows: March, 7.22° C.; April, 10° C.; October, 10.5° C.; and November, 7° C.

The evergreen trees, however, in a climate like that at Marquette would not be able to do so much work during these months, for the temperature is very much lower. In other words, in a climate with warm winters like that at Seattle, the evergreen trees can work more or less during the winter, early spring, and late fall months; while in a climate like that at Marquette, where the mean temperature is considerably below the freezing point during the winter months, this work would be very much checked if not stopped altogether. As one would expect, from this standpoint, the conifers would be more successful in the Puget Sound region than in the northern peninsula of Michigan. The conclusion that is reached from the foregoing is that, other things being equal, an equable distribution of heat is favorable to conifers. A reference to the temperature conditions in the Flathead valley will show that the climate is more equable than that at Marquette, but not so equable as that at Seattle. The coniferous forests are better developed here than at Marquette, but are not nearly so luxuriant as at Seattle. From the standpoint of carbohydrate manufacture, the deciduous trees are little or not at all affected by the temperature conditions of the non-growing season, for their leaves are absent, and consequently photosynthetic work is very much reduced.

A comparison of the temperature conditions at Kalispell and Columbia Falls shows a little difference, the latter being slightly colder. While this difference may affect herbaceous vegetation, it would likely have little or no effect on the forests; so the fact that there is no forest at Kalispell, while there is one near Columbia Falls will have to be explained on other than temperature grounds.

Transpiration, which also takes place during the non-growing season, will be discussed in another connection.

RAINFALL.

The greatest danger to trees is an excessive loss of water, and therefore the rainfall of a region is very important. It will be pointed out later how the conservation of this water supply influences the character of the forest. Other things being equal, the greater the amount of rain that reaches the earth, the more luxuriant the vegetation. The mean monthly and annual rainfall for Kalispell, Columbia Falls, Seattle, and Marquette are as follows, the amounts being given in millimeters:

TABLE II.

Stations	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
Kalispell	24	25	16	21	69	47	33	28	50	18	49	35	415
Columbia Falls	48	38	36	33	66	72	37	31	68	30	54	30	543
Marquette	52	45	47	51	76	89	77	73	99	83	69	62	823
Seattle	111	94	79	82	86	40	17	14	45	76	143	158	945

The difference in the amount of rain on the west and east sides of Flathead valley no doubt explains the difference in the types of vegetation in these two situations. It has already been shown that there is only a slight difference in the amount of heat at the two situations. It is very probable that the other elements of climate—light and velocity of wind—are about the same for the two places, although there are no data to prove this. It must be remembered that the towns are only thirteen miles apart, but the difference in rainfall is 128^{mm}. It is believed that this difference is sufficient to make a forest vegetation at Columbia Falls and only a prairie vegetation at Kalispell. Kalispell is well out in the valley, while Columbia Falls is at the base of the mountains. The rain-bearing winds from the west sweep across the high mountains west of the valley, where they lose a considerable portion of their moisture, and then descend into the valley where the higher temperature they encounter enables them to hold more moisture. This is liberated, however, when the winds bank up against the cool mountains east of the valley. Thus the west side of the valley probably has a rainfall of 400^{mm} or less and is not able to support tree growth except along streams; while the east side has a rainfall of from 400 to 543^{mm}, a sufficient quantity

to enable forests to exist. It is very probable that farther to the east in the mountains there is a still greater quantity of rain. At least the character of the vegetation would suggest that this is the case, for here the forest growth approaches in luxuriance that of the Puget Sound region where the rainfall is much greater.

A comparison of the rainfall in the valley with that of the Puget Sound region and of the northern peninsula of Michigan will lead to some interesting conclusions (Table II and *fig. 10*). In this comparison the data at Columbia Falls will be used rather than those at Kalispell, for reasons that are at once apparent. The character of

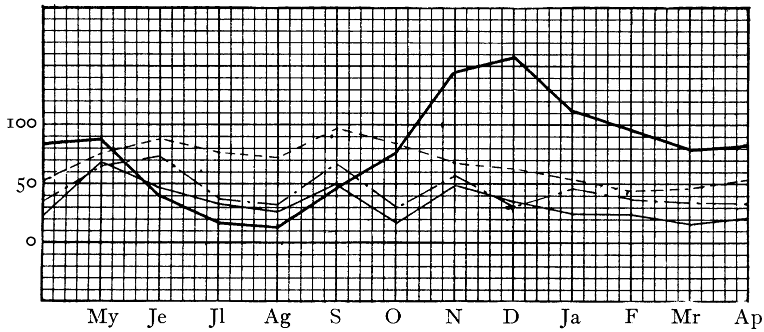

FIG. 10.—Comparative rainfall for Seattle (———), Kalispell (———), Columbia Falls (——·——·), and Marquette (------); the figures are millimeters of rainfall; summer rainfall highest at Marquette and exceedingly low at Seattle; in winter rainfall the reverse is true.

the distribution of the rainfall is of considerable importance. Thus at Marquette and Columbia Falls the rainfall is more or less evenly distributed thoughout the year, with the five warmest months, May, June, July, August, and September, having about half of the moisture. Thus these five months at Columbia Falls show a fall of 274^{mm} out of a total of 543^{mm}; and at Marquette 414^{mm} out of 823^{mm}. On the other hand, Seattle with its total of 945^{mm} has only 202^{mm} during these months. It is a well-known fact that the broad-leaved deciduous trees evaporate more moisture during the summer months than do the narrow needle-like leaves of the conifers. It is very possible that the 202^{mm} at Seattle and even the 274^{mm} in the Flathead valley are not sufficient to maintain the broad-leaved deciduous trees in these climates. In any event, they are absent in the two

regions, except along water courses, and are present in the Marquette region where they are more successful than conifers.

The winter distribution of rain is of extreme importance, especially to those trees that hold their leaves, for KUSANO[11] has shown that evergreen leaves transpire considerably even at temperatures below freezing. While there are no data to show whether the bare twigs of deciduous trees transpire more or less than those of conifers, yet *a priori* it is very likely that they give off less moisture, for they have less surface. If this be the case, conifers are more in danger of desiccation during the winter months than deciduous trees; for even though the amount of evaporated moisture is slight, it must be remembered that the ground may be cold or even frozen, and that absorption is thus checked. However, if the rainfall is sufficient and the relative humidity of the atmosphere is high, this danger is less. The figures will show that the winter rainfall of the Puget Sound region is excessive, while that of the Flathead valley and the northern peninsula of Michigan is equal in quantity to the summer rainfall. Conifers exist in all three situations. The extensive rainfall in the winter months at Seattle must be coupled with the fact that the temperature conditions during these and the early spring months are exceedingly favorable to certain physiological processes and account for the almost tropical luxuriance of the trees of that region.

RELATIVE HUMIDITY.

The relative humidity of the atmosphere is another factor closely associated with the amount of rainfall. The drier the atmosphere the greater the transpiration. Other things being equal, the nearer relative humidity is to absolute humidity, the less water will the trees give off, and the less danger will there be of their desiccation. The greater the saturation deficit, the greater the danger of losing water. The following table will show the mean monthly deficits of the three stations to be considered. Unfortunately there are no data from Columbia Falls.

The high averages of the saturation deficit for July and August for Kalispell, together with the small rainfall, probably account for the

[11] KUSANO, S., Transpiration of evergreen trees in winter. Jour. Coll. Sci. Tokyo **00**:313–366. 1902.

TABLE III.

Stations	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Kalispell	16.4	21.2	21.5	30.3	23.1	26.1	44.0	41.2	22.1	25.0	17.6	14.6
Marquette	16.5	16.4	19.7	23.7	27.0	27.0	27.6	23.3	22.3	19.8	17.5	17.4
Seattle	16.0	20.7	25.0	29.2	28.9	30.9	32.6	29.6	24.5	18.4	15.6	15.5

prairie condition there and on the west side of the Flathead valley. It must be emphasized, however, that the saturation deficit is of great importance only in connection with the amount of water available in the soil. If the ratio of the water obtained by the tree from the soil to that given off is $1:-1$, then the tree is in no danger of desiccation; if, however, the ratio is $-1:1$ or $1:1$, the tree is in danger of desiccation. From this it will be seen that if there is in the soil plenty of water that the tree can obtain, there will be tree growth though less luxuriant, even though the saturation deficit is high. This accounts for the existence of trees along streams even in prairie regions.

A comparison of the atmospheric deficits of Marquette and Seattle reinforces what was said concerning the rainfall of these two regions. It will be seen that both have a fairly low atmospheric deficit during the winter months, thus decreasing the possibility of transpiration at a time when the ground is cold. In the Puget Sound region the comparatively high temperature renders greater transpiration more likely than in the Marquette region, but this is offset by the fact that the temperature of the soil is no doubt warm, thus rendering available for absorption some of the great amount of water that reaches the soil in the form of rain during these months.

Again, a comparison of the atmospheric deficit data for the five growing months of the year shows a uniformly higher deficit for Seattle than for Marquette. This coupled with the fact that Marquette has a rainfall of 414^{mm} during these months against 202^{mm} for Seattle makes deciduous forests possible in the former region, but not in the latter.

VELOCITY OF WIND.

Another climatic factor that is likely to play a part in the distribution of the forest is the velocity of the wind. Perhaps the great-

est influence the wind has on trees is to increase the transpiration, and they more than any other form of vegetation are subject to the drying effects of winds. Indeed so important does SCHIMPER (pp. 542–555) think this factor that he considers it influential in bringing about the prairie condition. Below is given the mean monthly and annual wind velocities for the three stations. Again, there are no data for Columbia Falls, but the amount of wind is probably not very different from that at Kalispell. The figures are in kilometers per hour.

TABLE IV.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
Kalispell............	7.4	7.7	9.5	10.4	10.0	10.1	10.0	9.6	9.0	8.2	7.2	7.2	8.8
Marquette............	17.3	16.1	16.7	15.4	16.2	12.6	13.8	14.2	16.2	18.0	17.7	18.0	15.9
Seattle..............	10.3	11.1	10.9	10.4	9.5	9.0	7.6	6.6	7.4	8.0	10.1	10.7	9.3

As shown from these figures, one of the remarkable facts about the Flathead valley is the absence of excessive wind. It is believed that this, coupled with the rather low mean monthly temperature for the summer months, is what makes possible so luxuriant a forest, with a rainfall of about 500^{mm} In passing from the east side of the Rocky Mountains into the Flathead valley, the decrease in the amount of wind is very noticeable. Thus, Kipp on the east side of the Rocky Mountains has a normal rainfall of 512^{mm}, yet it has no tree growth. Although there are no data to show that there is more wind here than in Flathead valley, the fact is very apparent to one who has been in the two regions. It is believed that the excessive winds prevent the growth of trees, in spite of the fact that there is a rainfall of about 517^{mm}, or nearly as much as at Columbia Falls.

Compared with Marquette the wind velocity of Seattle is low. This would again favor a more luxuriant vegetation in the latter region than in the former.

SUNSHINE.

The more light, other things being equal, the more work trees can do. On clear days more food is manufactured than on cloudy days. This process can go on, as has been shown, during the non-growing season when the temperature is not too low, though the

amount of food manufactured then is much less than at higher temperatures. Light is the least variable of all the climatic elements. Possibly for a given altitude and a given latitude the variability is not great enough to have much influence on the kind of vegetation. However, the sunshine data may prove of importance in comparison with other regions. In the table below the mean possible hours of sunshine, which would be the same for a given latitude, and the mean actual hours are given. The observations cover a period of short duration.

TABLE V.

	January		February		March		April	
	Poss.	Act.	Poss.	Act.	Poss.	Act.	Poss.	Act.
Kalispell	276.2	88.2	286.8	111.8	370.1	180.7	410.4	240.2
Escanaba	283.1	85.3	290.4	120.5	370.3	129.8	407.0	178.4
Seattle	276.2	66	286.8	103.8	370.1	168.6	410.4	205.2

	May		June		July		August	
	Poss.	Act.	Poss.	Act.	Poss.	Act.	Poss.	Act.
Kalispell	471.3	231.4	479.8	279.6	483.2	364.4	442.5	269.6
Escanaba	464.1	163.8	471.7	218.7	475.7	211.5	437.6	230.5
Seattle	471.3	226.9	479.8	248.5	483.2	301.7	442.5	257.5

	September		October		November		December		Annual	
	Poss.	Act.	Poss.	Act.	Poss.	Act.	Poss.	Act.	Poss.	Act.
Kalispell	377.5	202.5	335.8	174.6	278.0	73	262.1	49	4473.7	2262.9
Escanaba	376.1	149.1	338.5	148.8	284.1	52.9	269.6	61.4	....	1727.1
Seattle	377.5	186	335.8	110	278	40.6	262.1	45	4473.7	1959.6

In his classification of climatic formations, SCHIMPER (pp. 556–565) does not recognize a distinct formation for the coniferous forest, placing it in what he calls the summer-green forest (deciduous). There is little doubt that he is right so far as the eastern part of the United States south of the latitude of Lake Superior is concerned. Here, as shown by COWLES (*l. c.*) and the writer (*l. c.*), the conifer-

ous forests occur as edaphic formations in the summer-green climatic formation. In this region they are xerophytic formations (societies) forming a stage in the progression toward the climax mesophytic deciduous forest formation. With the wearing down of the xerophytic hills, the filling up of swamps, and the accumulation of humus on the sandy plains and hills, the coniferous societies which now prevail there will give way to the climax deciduous forest, which is the highest expression of a climate similar to that found in the eastern United States.[12]

The Pacific coast district north of San Francisco, and including the moister mountainous regions inland, presents a climate entirely different from that of the eastern United States. Here, as compared with the eastern deciduous forest region, there is a more equable distribution of temperature throughout the year, with winter rains and excessively dry summers. The forests here are coniferous, with the deciduous element occupying only edaphic situations along water courses. It is my belief that in some such climate as that found in the Puget Sound region the coniferous forest is at its best, the deciduous type being unable to compete with it because of the dry summers.

The climate and character of the vegetation of the Pacific coast region corresponds more nearly with SCHIMPER'S sclerophyllous woodland (pp. 464–469, 507–540) than they do with his summer-green climate and vegetation. Indeed, elements of the sclerophyllous vegetation are found in the Puget Sound district, for here such trees as *Arbutus Menziesii* show a type of leaf decidedly like that found in climatic districts which SCHIMPER has so aptly called sclerophyllous woodlands. The sclerophyllous formations are in a climate with winter rain and comparatively high and equable temperature. Likewise the Pacific coniferous district has winter rains and a comparatively equable temperature, that is rather warm winters and cool summers. However, the mean average monthly temperature is much lower than that of the sclerophyllous districts of the warm temperature belt. This is no doubt influential in bringing about the narrow type of evergreen leaf rather than the broad type found in the warmer climate.

[12] See SCHIMPER (p. 545) for table showing rainfall of Atlantic forest district and Pacific coast.

For reasons given above, it is my belief that SCHIMPER'S summer-green climatic formation should not include the coniferous forests of the Pacific coast of North America, but that these should be separated from it. In order to show its relations to the broad-leaved sclerophyllous formation, I would suggest that it be called the *needle-leaved sclerophyllous formation*. The limits of this formation are not clear. While no doubt it reaches its best development in the Puget Sound region, this does not prevent its spreading into more northerly regions with cooler but still damp winters. Whether this type is the climax forest formation in the region north of the Lake Superior district, as it is on the Pacific coast, or only edaphic formations in the summer-green climatic formation of the United States, our present knowledge cannot determine.

The forests of the Flathead valley clearly belong to the needle-leaved sclerophyllous formation, but since they are on the border of a prairie climate they are not so good an expression of it as is that of the district farther west.

[*To be continued*]